PROCEEDINGS INTERNATIONAL SYMPOSIUM ON ENGINEERING GEOLOGY AND THE ENVIRONMENT, ORGANIZED BY THE GREEK NATIONAL GROUP OF IAEG / ATHENS / GREECE / 23-27 JUNE 1997

Engineering Geology and the Environment

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OFFPRINT / TIRE-A-PART

A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1997

Engineering Geology and the Environment, Marinos, Koukis, Tsiambaos & Stournaras (eds)
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Proposals for environmental impact decreasing in a suburban zone of limestone quarries: Southern Madrid Community, Spain

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ABSTRACT: Over 30 Mm^3 of limestones are extracted at least 100 quarries in southern part of Madrid, its environmental impact is described in this paper. Three main reclamation areas are distinguished: surrounding of quarries, faces or highwalls of quarries and the floor. For soil reclamation in the environs of quarries we suggest to sow it with forage of fast growth plants (*Lupinus, Tripholium...*), in the floor of quarries is possible a spontaneous revegetation or even may be reclaimed for agricultural uses. For quarried rocks faces previous blasting and/or wider benchs are proposed. In opinion of the authors it is necessary to concentrate the limestone extraction in two or three large quarries that allows a best policy and reclamation.

1 INTRODUCTION:

A surface of more than 6 Km^2 has been impacted to extract over than 30 Mm^3 of limestones in at least 100 quarries in southern part of Madrid capital (less than 30 Km from the city) (Fig 1). Some underground quarries (Colmenar de Oreja) was active three centuries ago; these quarries are historical sites to extract building materials for Madrid, mainly dimension stones (Dapena, Ordóñez & García del Cura, 1988). But the main extractive activity is focused in the last thirty years. At present the most important quarries are worked using areal strip-mining, but the quarries of small dimensions, non active at the moment, are contour strip-mining. Many of non active quarries are used as illegal urban and industrial waste disposal. Other visual impacts, together the highwall of the quarries, are the tips of excavation wastes and tailings: artificial hills and terracing.

2 RECOVERED MATERIALS:

The limestones extracted belong to the Upper Unity of Miocene of Madrid Neogene Basin. The general appearance of Upper Unity is liying subhorizontal and consist mainly in fluvial detrital sediments that in the uper part changes to massive limestones in the top of the Upper Unity. The thickness of limestones varies from 0 to 30 m, and the identified reserves are stimated up to 1000 Mt of highest chemical purity, that may be envisaged as ilimited for the present day demand of cement raw materials. Limestones may be clasified as biogenic carbonates: oncholitic, stromatolitic, tufa limestones and biomicrites (gastropoda, ostracoda, chara) are the most common facies (more information in García del Cura & others, 1994).

The average of chemical composition of limestones may be summarized as follows: SiO_2 less than 7%; CaO up to 49 %; Fe_2O_3 and Al_2O_3 less than 0.75 and 2.75 % respectively. The values of some critical components as SO_3, Cl^- and Na_2O+K_2O are always less than 0.7, 0.1, and 1 % respectively.

The average of limestones physical properties may be summarized as follows: water absortion, 1.73%; bulk specific gravity, 2,54 g/cm^3; comprensive strength, 90 Mpa; sonic velocity, 6,1 Km/s; Poisson's ratio, 0,36; and the modulus of elasticity 50.000 to 60.000 Mpa (more data in Dapena, García del Cura & Ordóñez, 1994).

The main uses of limestones are: a) Portland cement manufacturing; b) lime (quick lime and hydrated lime) manufacturing; c) crushed stones for Portland cement concrete and bituminous concrete plants; d) fillers; and e) dimension and cut stones.

The overburden of limestone are mainly reddish clay deposits with limestone boulders, that are related with some karstificacion processes associated even with small dolines. The Upper Unit of Miocene, and mainly

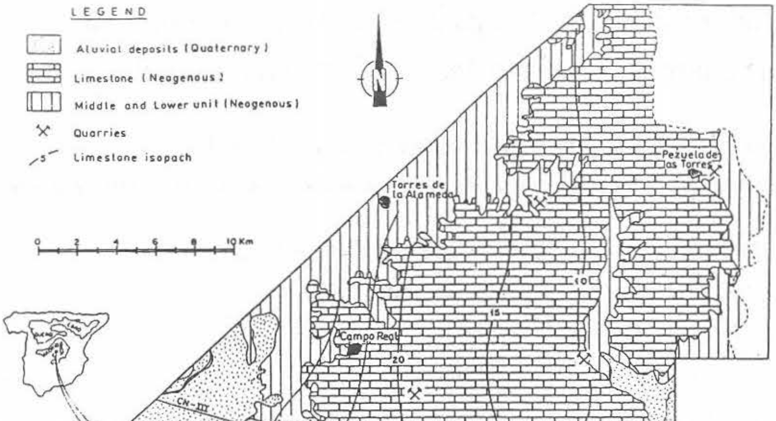

Fig 1. Location and geological map of the quarries zone. In the upper left part it shows a scheme of general location of the zone in Spain.

the limestones, are also the most important regional unconfined aquifer and the thickness of aireation zone is up to 20 m, consequently the limestones extraction and the using of the quarries as waste disposal may impact dangerously regional groundwaters.

3 ENVIRONMENTAL IMPACTS

The soil of the quarries zone is not well developped, its thicknes is less than 0,3 m, the vegetation is scarce, mainly brushwood and aromatic plants. Non - impacted soil cosists of an A-horizon that varies from argilaceous to arenaceous composition, and a K-horizon that is developped under the extracted material. Soils may be clasified as Aridisols or Inceptisols. As a consequence of their textures and structures these soils may be affected seriously by erosion.

The agricultural activities are focused in cereal of unirrigated land and olive groves. The olive groves are mainly located on soft materials where the A-horizon of soil has been destroyed by a previous defforestation and subsequent related erosion. The present-day erosion may be estimated by the fact that some young olive tree roots are 10 to 30 cm over the soil surface.

The most important quarries has been cartographied describe and quantify the following: a) anthropic morphology induced by extraction of limestones (highwalls, benchs,..); b) risks related with these morphologies (rock falls, rock slides; c) surface of zone exploited (holes, drainage network) d) mine wastes, tailings, crushed stone, stockpiles,...; e) natural revegetation (fig 2 and fig 3). Data from this specific cartography are used to stablish the environmental impacts and to make proposals for the environmental recuperation.

The temporal impacts may be summarized in relation with the specific activity in a semiarid region as follows: a) drilling and blasting in the quarries (noise and dust); b) crushing and screening plants (noise and dust); c) stockpile of crushed stone (dust); d) lime and Portland cement plants (dust and combustion gases); e) concrete plants (noise and dust). The permanent impacts are: a) quarries visual impacts, even from the air, because the zone is near Barajas airport, and the high of the near vertical faces are up to 10 m; b) quarries waste visual impacts; c) soils destruction; d) aquifer destruction and decreasing of water infiltration, and when the quarries are used as waste disposal, aquifer pollution.

4 QUARRY RECLAMATION

From the point of view of soils reclamation of quarries zone, we distinguish three main reclamation areas for each quarry,

- Surrounding of quarry.
- Faces of quarry.
- Floor of quarry.

4.1. *Surrounding of quarries*

These zones are not directly affected by extraction but some impact may be identified:

a) High rate erosion and dryness of soils even with gently slope, as a consequence of the excavation of quarry.

b) Dust and even boulder or blocks that cover the soil in the lower part of some tailings stockpiles.

c) Collapsed soils and damaged soils.

d) Low organic content in soils.

For soil reclamation in this area we may suggest to sow it with forage plants of fast growth plants (Lupinus, Tripholium...)

Before the sowing, soils ought to be manured and lightly fertilized. The biomass generated may be used to increase the organic content of soils. When the slope is up to 20% it is necessary to terrace the soils using small walls, or other common agricultural techniques to decrease the erosion rate.

4.2 *Quarried rock slopes (high walls)*

This is the most important visual impact of this mining activity, generally they are vertical and the highest wall is up to 10 m. Longitudinal extension may reach in the biggest quarries up to 400 m.

It is generally desirable to treat the surrounding quarry faces in order to reduce rockfall and to enhance the visual appearance.

It is possible to make landform replication with restoration blasting techniques on quarried rock slopes and using the civil engineering techniques that are commonly applied to road cutting. In this zone the construction of a landform similar to that in the sorrounding natural lanscape is easy to make because the arrangement of horizontal strata is very favourable.

We are in agreement with Gun & Bailey (1993) and Gagen, Gunn & Bailey (1993), after these authors the natural development of a blasted rock face is predictable and the stability of that areas of face (which will be more or less stable), can be identified by geomorphological mapping. In largest quarries restoration blasting aims to produce landform sequences by the construction of skeletal rock landforms which not only mimic the outward form of their natural counterparts but can be predicated to evolve in harmony with the operation of natural processes.

Commonly it is not possible the natural revegetation of quarry faces, only when the slopes are deeply modified using waste refill and/or blasting techniques. In order to obtain a cheapest and faster vegetation trial of this area is suitable to make 25 cm wide steps in the quarry face. The slope of steps (2-3%) has to be able to drain the rain water. Each slope may be imagined as a "window box" or "flower pot", that may be refilled with the wastes of explotation, and/or soil eroded in the upper part of the quarry face. The window boxes will be spontaneously collonized by indigenous sourrounding vegetation (*Aegilops geniculata, Avena sativa* and *Medicago sativa*, Arranz and Hidalgo, 1992) or may be artificially sown.

4.3. *The floor of quarries*

The floor of quarries consists mainly in marly and/or sandy sediments of middle permeability, commonly compacted by the stripping and transport machinery

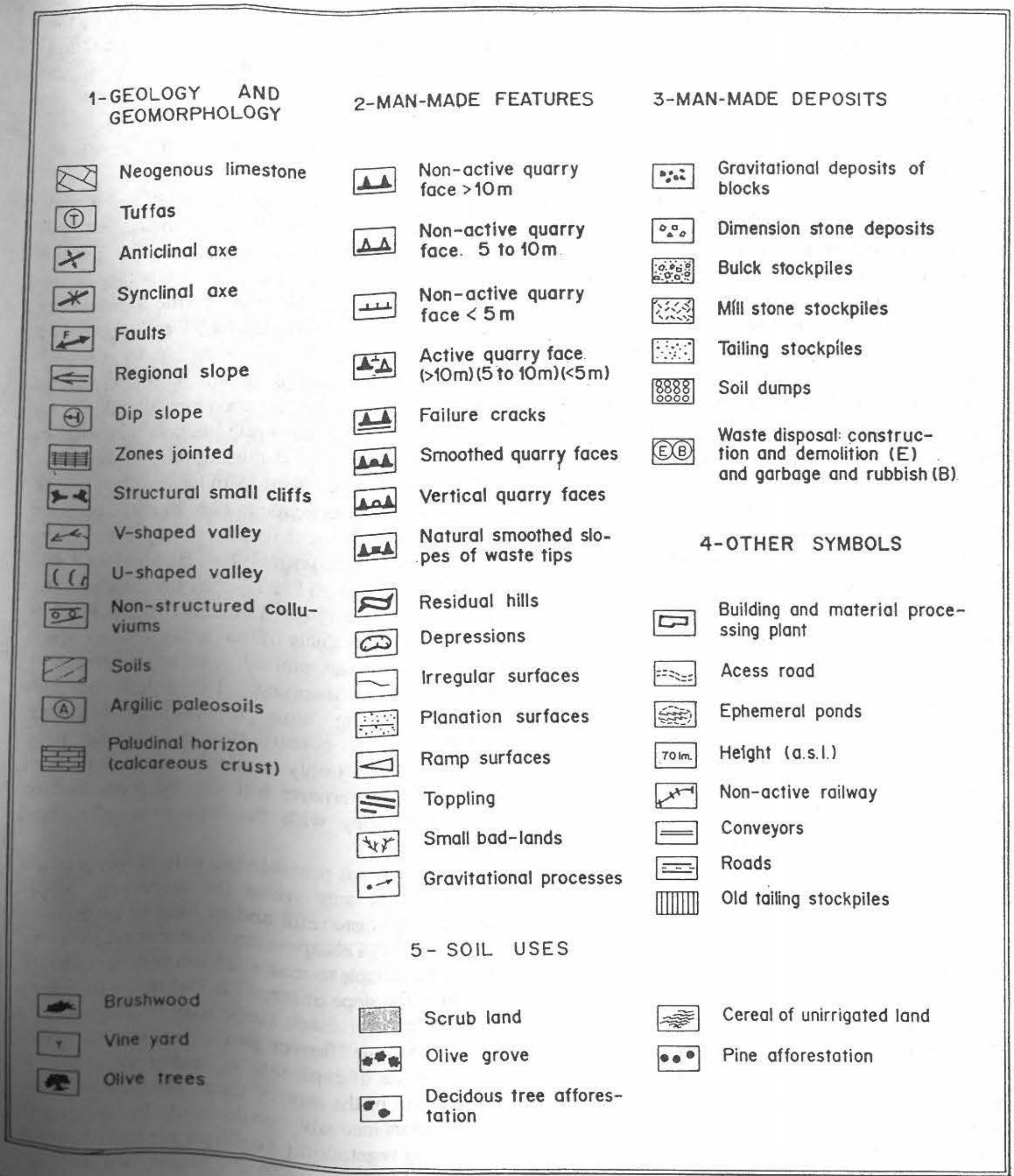

Fig 2 Legend used for mapping geomorphological, soil uses, man-made features and deposits. This legend is used for each of quarry zones identified. See the fig. 3.

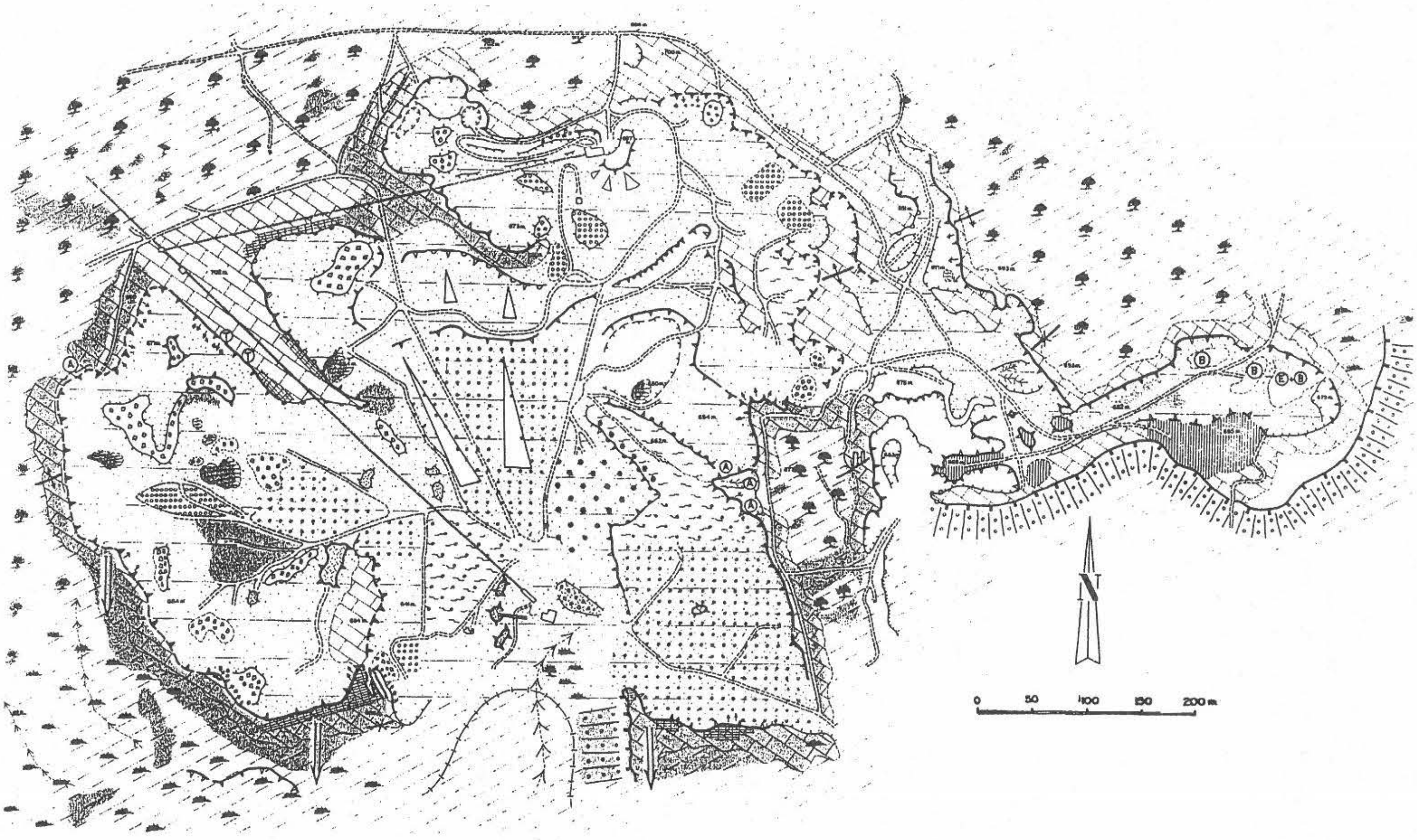

Fig. 3 Geomorphological and soil uses map of the quarries located western Arganda-Morata de Tajuña Road .

movement in the quarry. As a consequence of this compactation for the reclamation of this area the floor of quarries would be previously flat to avoid the development of ephemeral ponds in the winter, and after would be pluoghed to fluff up the soil. It is possible a spontaneous revegetation or even may be reclaimed for agricultural uses, as the climatic conditions are not adequate for afforestation (pine or decidous tree)

5 PROPOSALS FOR ENVIRONMENTAL IMPACT DECREASING

5.1 *Non active quarries*

The proposals for impact correction in non active quarries: a) The area strip-mining quarries: may be used after impermeabilization as parks, stadiums, parking, industrial land,.. and even as non toxic waste disposal. At the moment one of the most important non-active quarry, near Los Santos de la Humosa (N part of the map) is used as four wheel drive racetrack. Two big quarries, are used as legal waste disposal b) The contour strip-mining, ought to be restored to original contour using mining waste and tailings, or terracing and in any case reestablising vegetation. Semiarid climate of this region does not help the development of spontaneous revegetation.

The reclamation of small quarries, mainly contour-strip mining, would be start by a slope correction using the waste tips and/or blasting the quarry faces. The visual impact quarries as a consequence of the mining type is highest than other bigest quarries worked using areal strip-mining.

5.2 *Active quarries*

In the active quarries it is necessary:

a) To regulate news activities;

b) To restore soil and vegetation after extraction. The soil would be scraped and dumped, to use it in the mined areas reclamation. We suggest the use of natural revegetation, mainly indigenous brushwood species.

c) Mining companies licensed for rocks extraction ought to watch to prevent the dumped of dangerous vastes in the floor of the quarries, because of the high vulnerability of the aquifer lyng under limestone. The residence time of water in this aquifer is 15-30 years, after Maestro, Llamas & Rubio (1986), and as consequence the aquifer has a low capacity of self-purification.

d) A long-term proposal may be to concentrate the extraction of limestones in two or three sites. These bigger quarries, mined using areal strip-mining method, may be easily integrated from geomorphological point of view in the Páramo landscape, this may be considered as an erosional peneplain developped over Neogenous limestones and only locally trenched by the Quaternary fluvial network.

e) The concentration of the extractions of limestones may help the integral recovery of limestones. To draw up a plan for an integral explotation of limestones, and even of the overburden materials. This plan may be thought as a recovery by steps. So, after the extraction of blocks to obtain dimension and cut stones, some selected wastes may be used as raw materials for crushed stones, after this some wastes may be used for make fillers, and overburden, materialas and of course fines, and tailings may be used as raw material for clinker of Portland cement.

This study has been supported by the CAM (*Madrid Community Government*) (Research Project C 190-90).

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